WHO OWNS OUTER SPACE?

From Space debris to asteroid strikes to anti-satellite weapons, humanity's rapid expansion into Space raises major environmental, safety and security challenges. In this book, Michael Byers and Aaron Boley, an international lawyer and an astrophysicist, identify and interrogate these challenges and propose actionable solutions. They explore essential questions, from 'How do we ensure that all of humanity benefits from the development of Space, and not just the world's richest people?' to 'Is it possible to avoid war in Space?' Byers and Boley explain the essential aspects of Space science, international law, and global governance in a fully transdisciplinary and highly accessible way. Addressing the latest and emerging developments in Space, they equip readers with the knowledge and tools to engage in current and critically important legal, policy and scientific debates concerning the future development of Space. This title is also available as Open Access on Cambridge Core.

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WHO OWNS OUTER SPACE?

International Law, Astrophysics and the Sustainable Development of Space

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Introduction

The asteroid 101955 Bennu is just a pile of rubble, weakly held together by its own gravity, the remnants of a catastrophic event that occurred a billion years ago. But Bennu is also a bearer of both life and death, containing clues about the origins of life on Earth while, at the same time, having the potential to destroy humanity. For over time, the agencies of physics and chance have brought the 500-metre-wide asteroid onto an orbit very near to Earth.

A robotic spacecraft named *OSIRIS-REx* set out in September 2016 to make contact with Bennu. After many rehearsals, flying close to Bennu each time, the spacecraft made a brief landing – a 'touch-and-go' that enabled it to collect a sample from the asteroid's surface. Once *OSIRIS-REx* returns to Earth, scientists will spend decades analysing the 60 grams (or more) of material, which might turn out to include amino acids, the building blocks of life.

The *OSIRIS-REx* mission, however, is about more than science. NASA readily admits that the visit to Bennu is a prelude for possible mining operations, with governments and private companies hoping to extract water from asteroids to make rocket fuel – thus enabling further Space exploration and, perhaps, an off-Earth economy.[1] But some states oppose these plans, arguing that Space mining, were it to happen, would be illegal in the absence of a widely agreed multilateral regime. They point to the 1967 Outer Space Treaty, which prohibits 'national appropriation' and declares the exploration and use of Space to be 'the province of all [hu]mankind'. There are also reasons to worry that Space mining, if done without adequate oversight, could create risks – including the low-probability, high-consequence risk of an asteroid being inadvertently redirected onto an Earth impact trajectory.

[1] 'Space' is capitalized throughout this book to distinguish it from other uses of the word.

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Many current human activities in Space, and others planned or contemplated, raise the fundamental question: who owns Outer Space?

This book provides a detailed examination of a number of these activities and the different challenges they give rise to. But before we dive into the details, here are five more vignettes that serve as an introductory sampling of major challenges arising from the human development of Space.

Who Owns Outer Space?

A little Pomeranian called Saba missed out on the chance to join Sharon and Mark Hagle on the first of their four planned flights to Space, though Blue Origin did offer the dog a consolation prize – a specially fitted flight suit! As for the Hagles, they already have tickets for Virgin Galactic and are now in talks with SpaceX. Travelling to Space is an 'extraordinary' experience for the Florida-based couple, whose previous adventures included swimming with whales and abseiling into caves. 'My thought is you go, I go,' Sharon said of her 73-year-old property developer husband. 'Mark has always taken me out of my comfort zone.'

More and more of the world's ultra-rich are travelling to Space as tourists on short sub-orbital flights or much longer orbital flights, with increasing numbers going to the International Space Station. Trips around the Moon might also become a reality soon. Hollywood, unsatisfied with the visual effects provided by CGI or parabolic flights on aeroplanes, is right behind them, with Tom Cruise expected to fly to the International Space Station for a film shoot soon. It is all great fun, of course, unless one considers the environmental impacts.

Who Owns Outer Space?

The Soviet spy satellite Kosmos 1408, launched in 1982, ran out of propellant decades ago and became just another piece of Space junk . . . until it found a new purpose in life. It was chosen as a target for a powerful military to demonstrate a capability that everyone already knew it possessed – to destroy a satellite at will.

A ground-launched missile struck the 1,750 kg satellite at a relative speed of at least 20,000 kilometres per hour, creating a huge explosion and, at the same time, more than a thousand pieces of high-velocity space

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debris large enough to be tracked by ground-based radar. Tens of thousands of smaller but still potentially lethal pieces were also undoubtably created, many of them on elliptical orbits that cross the orbits of thousands of operational satellites, as well as the International Space Station and China's new Tiangong Space station. Immediately after the explosion, astronauts, cosmonauts and taikonauts retreated into the shelter of their capsules, which are hardened for atmospheric re-entry, and closed the hatches while the highest concentrations of debris flew by. That was not the end of the story, however. Some of the debris will remain in orbit for many years, posing an ongoing threat to all satellites, including many operational satellites belonging to Russia itself, the state that took this dangerous and completely unnecessary action.

Who Owns Outer Space?

A recently released framework for proposed mining activities on the Moon and other celestial bodies, called the Artemis Accords, includes a proposal to place 'safety zones' around these activities. The concept is borrowed from the quite different context of offshore oil drilling on Earth and from the United Nations Convention on the Law of the Sea.

'How can anyone be against safety?'

The assurances from Space agencies and foreign ministries are almost paternalistic in tone. At a minimum, the idea of safety zones seems like a solution in search of a problem, establishing a mechanism for drawing boundaries around ill-defined future activities. What is missing from such assurances is regard for the core principles set out in the 1967 Outer Space Treaty, that the exploration and use of Space is the 'province of all [hu]mankind', and that 'national appropriation' of the Moon and other celestial bodies is prohibited.

The reasoning advanced by the proponents of safety zones might almost be amusing if it did not contain within it the seeds of conflict. 'The boundaries are just advisory. They do not exclude anyone.' But will the United States say the same thing when astronauts or robots from another spacefaring state enter one of their safety zones without permission? How long do they expect these safety zones to remain in place, given that Space mining might require some of the most expensive infrastructure ever constructed? The answer: 'They're just temporary. They will only be used for co-ordination.'

Then why not just co-ordinate? Why are lines needed at all?

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Who Owns Outer Space?

SpaceX recently moved the bulk of its operations from California to Texas, attracted by the Lone Star State's low taxes and minimal regulations. The move may also have contained an implicit threat to the US government: the now-dominant Space actor could up stakes again, but next time to another country. Luxembourg, a well-established tax haven, would be an obvious place to incorporate. Although a tiny European country, it provides a friendly home for two of the world's largest operators of communications satellites in geosynchronous Earth orbit (GEO), and, in 2017, adopted legislation to facilitate commercial Space mining. SpaceX, meanwhile, has already acquired two large oil-drilling platforms that could be used to allow launches, quite literally, offshore.

Having launched more than 3,000 satellites since 2019, SpaceX now controls large swaths of Earth's most desirable orbits. Should one company, or indeed any actor, be allowed to use the most valuable parts of low Earth orbit (LEO) to such an extent that its use effectively excludes other actors from operating there safely? At what point does SpaceX exceed the carrying capacity of LEO and degrade spaceflight safety for everyone?

Tighter regulations are coming. But those regulations will be the result of negotiations, and companies, knowing this, are now working to establish the strongest possible negotiating positions. The emergence of Luxembourg and other 'flag-of-convenience' states in the Space domain will certainly help those who seek to minimise regulation.

SpaceX only exists because of NASA contracts provided to it when it was a fragile start-up. It still relies on NASA and US Space Force contracts for revenue, but the company is growing ever more powerful, launching thousands of satellites each year and planning missions to both the Moon and Mars. At some point, governments may find that they are negotiating with a leviathan that is both able and willing to transcend all boundaries.

Who Owns Outer Space?

In April 2019, *Beresheet*, a spacecraft owned by an Israeli foundation, became the first ever privately owned spacecraft to attempt a Moon landing. It ended up crashing onto the Moon's desolate landscape, destroying not only itself and its instruments, but also, most likely, its passengers. Those passengers were tardigrades, also known as 'water

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bears'. They had been smuggled aboard for no discernible purpose except, perhaps, for their mere presence – so that someone back on Earth could boast about where he had sent them.

Tardigrades are the hardiest life form known to humans, and it is at least conceivable that a few of them remain in a condition of deep stasis on the surface of the Moon, waiting to be reanimated under the right conditions. Yet the decision to place tardigrades in a Moon lander has received only muted criticism, when it should have been strongly and widely condemned. The real issue is not whether any tardigrades might have survived the journey, but that someone deliberately and successfully plotted to put life forms from Earth on another celestial body. A similar action, taken on Mars or one of the moons of Saturn or Jupiter, could wipe out any extraterrestrial life that might be present there – at enormous loss to science, and therefore to humanity's understanding of itself.

So Who Owns Outer Space?

All six of these vignettes concern real-life developments that took place between 2019 and 2022, when we were writing this book. We include them here to highlight the many ways in which people, states and companies think about Space, as well as how they go about their activities there. They also show how actions and decisions made today will matter greatly to all of humanity in the years and decades ahead. What succeeding generations choose to do will also be important, of course, and we cannot envisage all future scenarios. However, we and others already see major challenges ahead. Some of these require substantial shifts in the way Space is being used, while others may just require adopting more cautious behaviours. Either way, humanity needs to work together and take appropriate steps now, including developing new rules where necessary, if we are to avoid several extremely bad outcomes – not only in the long term, but including within just the next few years.

Many people believe that Space belongs to all of us. In January 2022, the Outer Space Institute partnered with the Angus Reid Group to survey a random sample of American adults about their opinions on Space. Of the 1,520 respondents, 81 per cent of them 'agreed' or 'strongly agreed' with the statement 'Outer space should belong to everyone; no one country should be able to claim control over it.'

Others are of the opinion that, far from Space belonging to everyone, it belongs to no one, and, for this reason, that no parts of it can be owned.

Yet others agree that nobody owns Space, in general, but believe parts of it can indeed be owned.

Whichever position is taken, one inevitably runs into questions concerning actions – for example, what restrictions should be in place if somebody wishes to mine an asteroid or the Moon? Is it acceptable to mine asteroids, just because there are so many of them? Or if parts of Space can be owned, which parts? An entire asteroid, a small lunar crater, or perhaps only extracted resources? Finally, there is the most important question of all: who decides on the existence and content of rules, and on their application to specific situations?

Whatever Space is, states, companies and even wealthy individuals are rushing to assert dominance over it – to exploit resources, to pursue science and exploration, and, in some cases, simply to show off. Many of these actors are enormously enthusiastic about the technological and economic achievements that might be possible in Space. Far fewer of them seem to have given much thought to the considerable risks for Space missions, for those who undertake them, and for the environment in Space and on Earth.

This book examines a selection of 'grand challenges' that have emerged very recently because of the rapid expansion of human activity in Space. By 'grand challenges' we mean problems that exist on a scale that implicates all of humanity and must be solved for our civilisation to prosper, and indeed, in some cases, to survive. The most recent of these challenges is the invasion of Ukraine, which has brought the risk of an all-out nuclear war back into sharp focus. Russia's actions matter for this book because they threaten the political cornerstone of Space governance, namely the six decades of close co-operation between Moscow and Washington that led, first to the creation of the United Nations Committee on the Peaceful Uses of Outer Space in 1958, and then the International Space Station. It is there, on the ISS, that, thankfully, that Russian cosmonauts and Western astronauts still work side by side.

It should be apparent that grand challenges cannot be understood from a single disciplinary perspective, or even multiple disciplines working independently. Legal and policy solutions must be grounded in a firm understanding of the constraints imposed by physics and the uncertainty in our knowledge of events and outcomes. And although innovation and technological advances continually open new pathways for humanity to use and explore Space, it should also be apparent that no grand challenge has a purely 'technical' solution. As with climate change, pandemics and inter-state wars, grand challenges in Space require solutions that are grounded in a firm understanding of why and how countries co-operate, and how they seek to stabilise and channel that co-operation through international law. For all these reasons, this book takes a transdisciplinary approach to investigating grand challenges and identifying possible solutions. From start to finish, we have fully integrated our expertise in astrophysics, international law and international relations.

Space debris is an excellent example of a grand challenge that can only be solved through transdisciplinary research and analysis. Yet most people conceptualise the problem in ways that make the problem worse. They see Earth orbit as a near-infinite and therefore inexhaustible void, when it is in fact a finite resource. It is the same kind of misunderstanding that led to the plastics crisis in the oceans, and the climate change crisis in the atmosphere. If you throw enough stuff away, even the largest environment will become overloaded and begin to break down.

When multiple actors are contributing to the overload, we have a 'tragedy of the commons' – the quintessential 'collective-action problem', whose dominant feature is that individual actors can believe that everyone else must take steps to solve the problem, while not taking those steps themselves. These non-co-operative actors are 'free riders' who make no changes to their own behaviour while enjoying the additional benefits of everyone else's co-operation. Thus one path towards 'sustainable development' is to foster co-operation and discourage free riding.

All of the terms in quotation marks in the previous paragraph will be familiar to many readers. We use them to underline the point that Space is properly seen as an issue of global environmental politics, using many of the same conceptual and analytical tools.

But while many are familiar with the above concepts, we must recognise that the 'Space-is-big' mentality persists and has very powerful supporters, including Elon Musk. In December 2021, the founder and CEO of SpaceX assured the *Financial Times* that 'tens of billions' of satellites could safely be placed in LEO. 'Space is just extremely enormous, and satellites are very tiny,' he said. According to Musk, orbital shells as shallow as ten metres could be employed, in which case, 'A couple of thousand satellites is nothing. It's like, hey, here's a couple of thousand of cars on Earth – it's nothing.'

The comparison might seem to make sense at first glance, with some types of satellites having similar sizes to cars, at least without their solar panels. But there are serious flaws in this thinking. Cars barely move when compared with satellites, which orbit the Earth every one and a half to two hours in LEO. Satellites thus sweep out a large volume each orbit, with lots of potential for interactions. Cars, moreover, are very manoeuvrable and can slow down when traffic becomes congested. Satellites can make only minor course corrections, barely changing speed. There are also vast numbers of small, undetectable but still lethal pieces of debris and meteoroids to contend with, as well as destructive, unexpected equipment failures such as battery explosions.

Indeed, a major satellite–satellite collision has already taken place, with Iridium 33 and Kosmos 2251 striking each other in 2009 – a time when there was a relatively low density of satellites in orbit. Today, the congestion in LEO is only increasing, stressing operators seeking to maintain a safe working environment for their satellites.

Technological advances can play an important positive role, including various levels of automation that will aid human decision making and enable satellite-based collision avoidance. But caution is required. Automation can still lead to catastrophic failures, as we have seen in the aviation industry. Moreover, if a technology allows for the dense operation of satellites, then the increased efficiency and accessibility of LEO can stimulate even higher demand for its use.[2] This, in turn, can lead to even greater densities and with them renewed stress on the environment. Of particular concern are the consequences of any debris-generating event that takes place in a crowded orbital region, due to the corresponding elevated risk of knock-on collisions.

The growing awareness of humanity's reliance on LEO is bringing the Space debris challenge into the spotlight, and with it ideas to clean up the orbital mess. Even so, most of the proposed solutions that aim to 'clean up' debris do not, or cannot, account for the still-lethal pieces that are too small to be tracked. The automated collision avoidance systems noted above would enable satellites to dodge large debris and other satellites, assuming no errors, but they cannot avoid small debris and meteoroids. And while some technologies, such as those that would enable large rocket bodies to be removed from orbit, will have to be part of an overall solution, they do not address the fundamental problem of overuse, which

[2] This hypothetical situation highlights a class of well-known problems associated with the Jevons paradox, which observes that technological improvements, by increasing the efficiency with which a resource is used, reduce its cost and thereby increase demand, negating the efficiency gains.

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is continuing at breakneck speed and seems destined to overrun any technological 'fix'.

Sustainable development of Space will only come with the adoption of new best practices. One example, for the sake of the present discussion, might be to limit the number of satellites that a single company can launch – to incentivise operators to focus on increasing the longevity, capabilities and resilience of individual satellites, rather than building huge constellations of cheap mass-produced ones. Restrictions like this, if done well, would not undermine the commercial development of Space. They would instead maximise the potential for long-term growth while minimising environmental and other negative impacts in Space and on Earth. There are many good examples of sustainable resource management on Earth, often involving two or more otherwise competing countries, such as the four-decades of ongoing co-operation between Norway and Russia to both protect – and thus, over time, maximise – the world's largest cod fishery in the Barents Sea.

Of course, if limiting access to a resource turns out to be part of the solution, one immediately runs into questions of governance and of who, ultimately, gets to decide. But even on issues that involve hundreds of states, and that concern 'areas beyond national jurisdiction', there are many good Earth-bound examples of how this can be achieved. We discuss some of these examples in this book, in part to inspire those who worry that Space might become a 'Wild West' dominated by a few powerful and antagonistic actors. There is, indeed, another way.

At the same time, the best forms of governance take a light touch, intervening in human ingenuity and enterprise only when necessary. For this reason, understanding the ways in which Space is a resource, how it is being used and whether it is being depleted is critical to establishing effective and equitable long-term management. In ecological terms, it requires knowing what any given actor's 'footprint' is in Space, and what the 'carrying capacities' are for different orbital regions. This directly ties into the concept of Space as an environment, which is finally gaining international recognition, as well as into recognising that the Space and Earth environments constitute a single interconnected environment. This book supports this understanding by showing how Space activities, whether launches, re-entries, or the placement of thousands of reflective objects in the sky, can cause environmental damage and interfere with activities on the surface of the planet.

We thus come full circle. The expertise of Space scientists is needed to identify challenges before they become unsurmountable, and to propose practicable solutions. Social scientists and lawyers are needed to ensure that solutions are politically feasible, and to carry them forward into lasting rules and institutions. Engineers are needed to develop technologies that can be used in beneficial ways, with environmental scientists guiding us forward by identifying what is beneficial, and what might not be.

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